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**A MULTISPECTRAL TERRAIN
DATABASE DEVELOPMENT
PROCESS TO SUPPORT LEGACY
MISSION SIMULATION
ENVIRONMENTS**



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A Multispectral Terrain Database Development Process to Support Legacy Mission Simulation Environments

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ABSTRACT: *The Air Force Research Laboratory, Air Vehicles Directorate, Control Sciences Division, AFRL/VAC, has developed a process for constructing large-area 3-D multispectral terrain databases to support Simulation Based R&D (SBR&D) concept development simulation, research and T&E activities. The Multispectral database (MsDB) development effort was intended to investigate a database development approach built from multispectral/hyperspectral imagery and elevation data that also incorporates material classification data capable of supporting realistic out-the-window visual and multispectral terrain displays and weapons/sensor models. Integrating the MsDB into these legacy models enabled us to develop cockpit representations that immerse the warfighter, scientist, analyst, and testers into a dynamic environment suitable for engineering level test and evaluation of a multitude of systems. This paper covers integration of the MsDB with Paint the Night IR Scene Generation; integration with Mutli-Mode Radar Simulation (MMRS), which provides Synthetic Aperture Radar Simulation; and integration with SubrScene, which provides Out-The-Window Scene generation.*

1. Technical Challenges to be Addressed

In order to provide Air Force Research Laboratory, Air Vehicles Directorate, Control Sciences Division (AFRL/VAC) a fully functional and cost-efficient multispectral scene generation capability, several challenges must be addressed:

- Authoritative representations of the synthetic natural environment, including geospecific SEDRIS transmittals, must be richly populated, sufficiently documented, efficiently organized, and possess sufficient fidelity to meet the requirements of scene generation systems which also are linked to real-time environmental databases and HLA-compliant servers.
- State-of-the-art phenomenological models must be accessible to both database generation processes and the real-time/runtime simulation environment. This implies closer linkage between environmental data collection processes and runtime environmental models.

2. Team Experience and Capabilities

Air Force Research Laboratory, Air Vehicles (AFRL/VA), Sensors (AFRL/SN) and Munitions (AFRL/MN) Directorates, in conjunction with the U.S. Army Redstone Technical Test Center (RTTC) and U.S. Army Communications and Electronics Command (CECOM) Night Vision and Electronic Sensors Directorate (NVESD), is currently developing a common Multispectral Database (MsDB) for applications in AFRL. The current database prototype development covers a 2° x 2° region, and will be expanded incrementally to 32°. This database will be able to support electro optical/infrared (EO/IR), radar/RF and optical (e.g. out-the-window) scenes at DTED Level 2

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elevation and complementary feature accuracy and resolution; it is also being produced to support complementary constructive and semi-constructive models such as Joint Integrated Mission Model (JIMM), JSAF and OneSAF Testbed. AFRL/VA, RTTC, and NVESD have signed a Memorandum of Agreement (MoA) that governs collaboration on this and related projects.

3. Advanced Concepts

The AFRL team is also conducting collaborative research into high-resolution real-time graphics solutions on low-cost PC platforms, as well as mid-to-high cost massively parallel approaches to real time multispectral sensor simulation. In addition, research continues on development, integration and evolution of real-time simulation technologies such as model-to-hardware interfaces, closed-loop simulation technologies, and improved Radio Frequency simulation fidelity. All three partners have operational real-time sensor scene generation systems based on Silicon Graphics™ Onyx Reality Engine platforms, which support 12 to 48 bit texture rendering and a system bandwidth ranging from 11-716 gigabytes per second. The NVESD Paint the Night EO/IR scene generation package is one of the AFRL team systems that make full use of these high-performance computational assets. Due to recent technological advances in low-cost (hundreds to thousands of dollars) PC graphics acceleration hardware, high-performance computing systems based on Linux PC (e.g. "Beowulf") clusters, and network bandwidth, the AFRL team is exploring the scene generation trade space to determine which hardware and software solutions offer the best value in terms of scene fidelity, real-time performance, adaptability and ease of development. Innovative rendering technologies, including ray tracing methods, are being explored together with traditional textured polygon rendering methods, in order to enhance the ability of graphics engines improve the robust fidelity of specific environmental phenomena. These include, but are not limited to such optical effects as light scattering, shadows, reflection, turbulence and an order of magnitude increase in emissive energy sources available to the scene generation system. The AFRL team has a strong commitment to make best use of DMSO products and standards, including HLA and SEDRIS, in conjunction with these initiatives.

4. Multispectral Database (MsDB) Development Process

4.1 Overview

Our large area 3D multi-spectral terrain database is fundamentally composed of remotely sensed multi-spectral imagery, ground elevation, and material classification feature data. The U.S. Army Redstone Technical Test Center (RTTC) is responsible for defining requirements for and initially processing this data for further integration into a run-time digital terrain database. In the following sections, we discuss the requirements definition, image processing workflow, and the imagery derived products produced by RTTC.

4.2 Requirements Definition

We begin the MsDB development process by defining the imagery, elevation, and material classification feature requirements. These requirements will determine the input data we acquire and the processes we implement to meet the goals of this particular effort. We first determine source imagery from which to develop our database. We consider a number of factors as we determine the imagery source. These factors, among others, include:

- Security classification of database
- Necessary imagery spatial and spectral resolution
- Region of interest land area size
- Hard disk space necessary for imagery
- Data availability and acquisition costs for imagery
- Processing costs for imagery
- Target usage of the terrain database

In the following section we provide a brief overview of these factors that help us determine our final processing workflow. The desired security classification for this project is UNCLASSIFIED. We can process and extract information from CLASSIFIED imagery sources. However, we consider a core set of UNCLASSIFIED remote sensing data from which to choose for this effort. This set includes Ikonos, Quickbird, SPOT5, and Landsat 7

ETM+. This is not an exhaustive list of sources. However, based upon previous research and production experience we believe these are the most appropriate options for this application. It should be stated that we have examined the efficacy of integrating Controlled Image Base (CIB) data from NIMA. Though we can readily ingest and utilize CIB data, the image tonal quality is not suited for our final product. Therefore we have not included this as a possible data source for the purposes of this paper. In the following section we provide a brief description of the sensors we have chosen to consider.

Ikonos is a commercial satellite launched in September 1999 by Space Imaging, Inc. Ikonos imagery is available in various formats and processing levels. The basic data specifications for Ikonos imagery is:

Spectral Band	Wavelength (μ)	Spatial Resolution (m)
Panchromatic	~(0.45-0.90)	1
Blue	~(0.45-0.52)	4
Green	~(0.51-0.60)	4
Red	~(0.63-0.70)	4
Near IR	~(0.76-0.85)	4

Quickbird is a commercial satellite launched in October 2001 by Digital Globe, Inc. Quickbird imagery is available in various formats and processing levels. The basic data specifications for Quickbird imagery are:

Spectral Band	Wavelength (μ)	Spatial Resolution (m)
Panchromatic	~(0.45-0.90)	~(0.61-0.72)
Blue	~(0.45-0.52)	~(2.44-2.88)
Green	~(0.52-0.60)	~(2.44-2.88)
Red	~(0.63-0.69)	~(2.44-2.88)
Near IR	~(0.76-0.90)	~(2.44-2.88)

SPOT5 is a commercial satellite launched in May 2002 by SPOT Image. SPOT5 imagery is available in DIMAP format and various processing levels. The basic data specifications for SPOT5 imagery are:

Spectral Band	Wavelength (μ)	Spatial Resolution (m)
Panchromatic	~(0.48-0.71)	2.5 or 5
Green	~(0.50-0.59)	10
Red	~(0.61-0.68)	10
Near IR	~(0.78-0.89)	10
Short Wave IR	~(1.58-1.75)	20

The Landsat program is a joint initiative between the United States Geological Survey (USGS) and the National Aeronautics and Space Administration (NASA) which began in the early 1970's. The Landsat 7 satellite was launched in April 1999. Landsat 7 ETM+ is available in various formats and processing levels. The basic data specifications for Landsat 7 ETM+ imagery are:

Spectral Band	Wavelength (μ)	Spatial Resolution (m)
Panchromatic	~0.72	15
Blue	~0.48	30
Green	~0.56	30m
Red	~0.66	30m
NearIR	~0.83	30m
MidIR	~1.65	30m
MidIR	~2.2	30m
Thermal IR (L&H)	~11.45	60m

From these sources we may choose from spatial resolutions varying from 0.61m to 60m. Each sensor offers a panchromatic band in addition to at 4 multi-spectral bands. These multi-spectral bands will provide information for extracting vegetation and other material signatures.

Our overall goal is to produce a large area terrain database to include a land area of 32°. This area encompasses approximately 780,000km². The bounding box for this area is shown in figure 1.



Figure 1: Map of entire 32° 3D terrain database region.

We will begin by developing a $2^\circ \times 2^\circ$ prototype region, and then incrementally build outward until the entire 32° is complete.

Disk space is not a trivial issue when dealing with imagery. We must consider this to ensure we establish the proper processing infrastructure to efficiently work with large imagery sets. As stated previously, we have defined an overall database are of $\sim 780,000\text{km}^2$. The following table states the approximate disk space needed to cover this entire area using the source imagery we are considering.

Sensor (Resolution, # Bands)	Quickbird (0.61m, 4)	Ikonos (1m, 4)*	SPOT5 (2.5m, 3)	Landsat 7 ETM+ (15m, 6)
Disk Space (GB)	~ 8.4 TB	~ 6.26 TB	~ 376 GB	~ 20.9 GB

* 11 bit data All other data is 8 bit data

Acquisition cost for imagery is another factor we must consider. These remote sensing platforms provide valuable information which is reflected in the purchase price. The following table states the imagery acquisition costs to cover the entire 32° area.

Sensor	Quickbird	Ikonos	SPOT5	Landsat 7 ETM+
Price per km^2	\$30	\$27	\$2.81	\$0.02
Total Cost	\$23,496,750	\$21,147,075	\$2,200,862.25	\$15,105.59

The acquisition costs for this imagery gives rise to the availability of this data. Although it is possible to purchase this data directly from the various providers, it is desirable to reuse valid imagery sets already available to DoD projects. By working with the National Imagery and Mapping Agency (NIMA) we are able to search the Commercial

Satellite Imagery Library (CSIL) archive and request available data at no cost and utilize such data for the development of our 3D multi-spectral terrain database. This allows us to attenuate the acquisition costs to a great extent.

The target usage of the terrain database is for simulation, training, and experimentation. We are not developing a database intended for targeting purposes. Though we process the input data to achieve accurate registration, we are not constrained by rigid accuracy requirements such as are needed for targeting purposes.

Now that we have briefly described the factors for determining imagery sources, we move to a discussion of the elevation and feature data. The requirement has been established that we use Digital Terrain Elevation Data (DTED) level 2 elevation data. DTED 2 data is ground earth elevation data with a post spacing of ~30m. DTED data is available from NIMA over a large portion of the globe. However, DTED level 2 complete global coverage is not fully available yet. Therefore we consider alternative processing methods of DTED level 1 data to reach the desired post spacing of 30m. There are other options for elevation data, which we will discuss later.

Finally, we consider the feature data that we must extract. The requirements set forth for this effort are to extract:

- Roads
- Rivers
- Area bodies of water
- Building footprints
- Railroads
- Vegetation

There are a number of feature sets already available over areas of the globe that include these features with varying levels of material attributes. NIMA provides VMAP data over areas of the globe at varying resolutions as one example. However, these data sets are not fully available with global coverage, and these features may not be precisely correlated to rectified high-resolution imagery. Therefore, we look to extracting new feature sets based upon medium to high-resolution remote sensing data. We can spatially extract the aforementioned features from panchromatic or visible color imagery using manual and semi-autonomous extraction methods. However, we must utilize multi-spectral data to extract material classification information for these features. Therefore, we must identify an appropriate imagery source containing multi-spectral information, and not simply panchromatic or visible color.

Based upon these factors we have established a set of requirements from which we begin our development. We begin by establishing a foundation imagery base using Landsat 7 ETM+ imagery. Using this imagery we create a 15m, pan-sharpened, multi-spectral imagery mosaic over the 2° x 2° prototype region of interest. From this data we extract features with their material properties using this imagery. We have examined existing feature data available over this region and have determined to incorporate VMAP Level 1 data only over areas over which we do not have sufficient multi-spectral imagery coverage. Once we complete the entire Landsat 7 ETM+ processing stage, we identify high priority areas within this region and incorporate 2.5m SPOT imagery. Using this imagery we extract higher spatial resolution features that are correlated with the features previously extracted from the Landsat data. For the elevation data we utilize existing DTED level 2 data, where available. Where DTED level 2 data is not available, we resample DTED level 1 data to reach the desired post spacing of ~30m.

We have defined our initial requirements list and are ready to begin processing the data. This requirements list may change throughout the process as new data sources are made available. However, the same basic workflow will still apply.

4.3 Image Processing Workflow

We begin the image processing workflow by acquiring the necessary imagery, elevation, and existing feature data. We request DTED and VMAP feature data directly from NIMA. We search the CSIL archives for existing imagery over the entire 32° region. Though we are initially focusing on the development of a 2°x2° area, it is most efficient to search the entire area at one time in order to generate a data coverage map for future reference. From our initial query and request, we acquire sufficient Landsat 7 coverage from the CSIL over AOI #1. We begin by examining

the imagery and performing rectification when needed. Once the images are properly rectified, we mosaic and tonally balance the imagery. We first mosaic the panchromatic bands, then the 30m multi-spectral bands separately. Figure 2 shows the tonally unbalanced input imagery we have over this particular region.

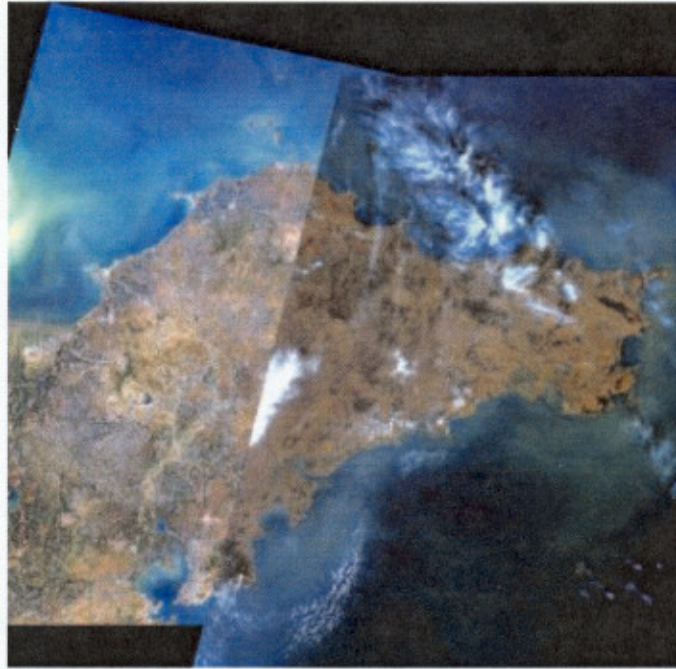


Figure 2: Tonally unbalanced image mosaic displaying image quality prior to histogram processing and feathering.

This sample mosaic displays the clouds, seasonable, and other atmospheric differences that must be attenuated or eliminated to produce a suitable seamless image mosaic. It should be stated that the ideal solution to these obscurations is to acquire a series of images collected at or near the same time under cloud-free conditions. We take this approach later as we integrate higher resolution SPOT5 imagery. However, at this point we are simply laying down a low-resolution foundation, over which we will mosaic higher resolution imagery incrementally as the project continues. Therefore, we simply attenuate these obscurants at this point and move on to mosaicking the imagery.

We first attenuate the color differences by altering the histograms of each color channel to match the adjacent image. We implement a form of histogram specification to achieve these desired results. We then utilize outline feathering to eliminate the presence of clouds as much as possible. The final result is a virtually seamless image mosaic shown in Figure 3.

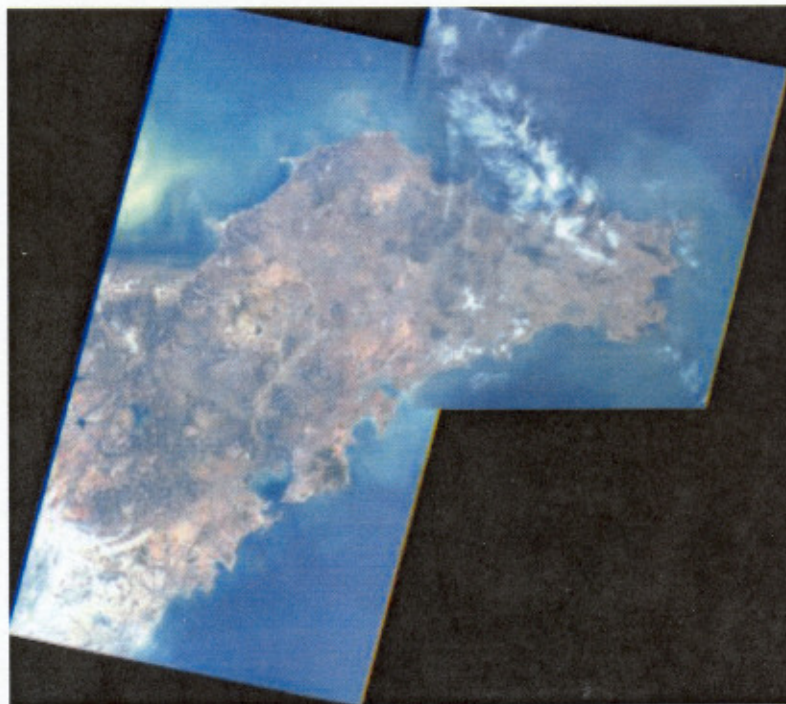


Figure 3: Tonally balanced image mosaic after histogram specification and outline feathering.

This color mosaic is composed of three separate Landsat 7 scenes collected in May and October of the same year. We mosaic and tonally balance the 15m panchromatic and 30m multi-spectral bands separately. Finally we implement a pan-sharpening algorithm to generate a 15m-resolution natural color image. The final products of this stage are a tonally balanced 6 band, 30m resolution multi-spectral image to be used for feature extraction and a tonally balanced 15m natural color image used to directly feed the OTW visualization and to spatially enhance the feature extraction from the 30m resolution data.

Our feature extraction goals for the $2^{\circ} \times 2^{\circ}$ prototype region include some basic features listed previously. We begin by first identifying vegetation. Using the 6 band multi-spectral mosaic, we implement a series of supervised pattern classification algorithms to identify vegetation present in the scene. Then we identify the vegetation type by matching the spectral signatures of the extracted classes with existing spectral libraries we have resampled to correlate with the wavelengths consistent with Landsat 7 ETM+ data. Next we identify water features such as rivers, lakes, and ocean boundaries. We initially extract these features using supervised classification algorithms, and then refine the extracted boundaries manually. We then identify road and railroad linear features in the scene. Although some supervised classification algorithms may be used for extracting these features, it is more efficient to manually extract these features then perform spectral matching to identify the material type for the roads. Finally we manually identify building footprints in the imagery. Due to the relatively low spatial resolution of Landsat imagery, 15m, we are unable to identify exact building footprints for an average sized building. Therefore we identify the bounding boxes for built-up areas containing multiple buildings. When possible, we extract building footprints for extremely large buildings as well. Using higher resolution imagery, we may extract building footprints, and we discuss this later in the paper. An example of our feature extraction is shown in Figure 4.

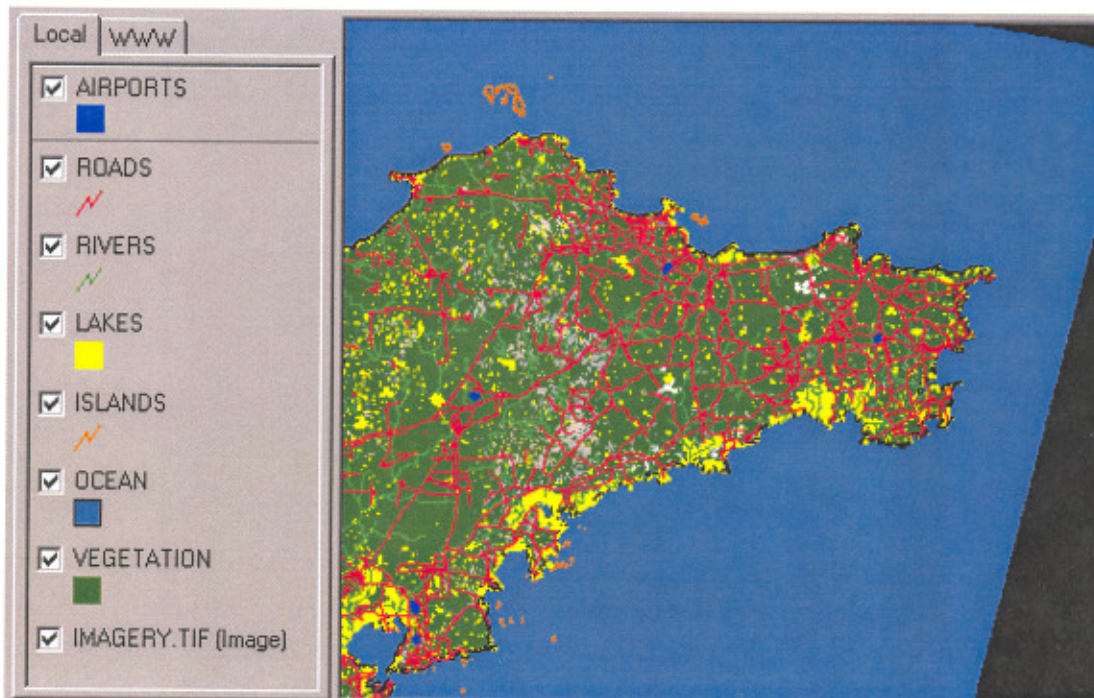


Figure 4: Overview of georeferenced extracted features.

Once we have extracted these features, we assign attributes to them. For the respective features we provide vegetation type, soil type, road surface type, road width, and river width. We then export these feature vectors to attributes 2D Environmental Systems Research Institute (ESRI) Shapefiles. The features are then used further in the synthetic scene generation process.

Finally, we resample the available elevation data to 30m post spacing. After inspecting the final elevation data, we export it to usable format for further integration. At this time we use a GeoTiff format for the elevation data. We may also export the data into a variety of standard formats such as DTED, USGS Digital Elevation Model (DEM), or other suitable georeferenced binary format. These formats depend upon the needs of the end user.

In summary the final output products for our initial work using Landsat data are:

- 15m pan-sharpened natural color image in GeoTiff or NITF format
- 30m post spacing elevation data set in GeoTiff, DTED, DEM, or NITF format
- Attributes feature set in Shapefile format including
 - Built-up areas
 - Roads & railroads
 - Rivers
 - Lakes
 - Ocean
 - Vegetation

The products may be reused for integration with other terrain database efforts. We also maintain the original imagery and elevation data for further updating and rectification as needed. Therefore when new imagery is collected over these areas, we can rapidly integrate this data into the existing mosaic and generate a new tonally balanced mosaic for further reuse. One underlying goal in this effort is to produce imagery derived products that may be widely reused. In order to achieve this, we must provide the data in a wide array of formats. We have previously presented specific formats in which we deliver the data to NVL and AFRL. However, we have the ability to provide this data in a number of other formats to meet customer requirements. As we proceed in this effort, we will define the most needed formats and ensure our ability to export efficiently to those formats.

To this point we have provided a basic overview of the image processing workflow using Landsat 7 ETM+ imagery. Using this data we have generated an image foundation with a spatial resolution of 15m. We now proceed to integrating newly acquired SPOT5 imagery into the scene to reach a higher spatial resolution.

4.4 Higher resolution imagery integration

At this time we have chosen to acquire SPOT5 data instead of Quickbird and Ikonos for higher resolution imagery work because it provides the best tradeoff between resolution, spatial footprint, and price. We are able to acquire a 60km x 60km SPOT5 bundle for about one tenth of the cost of Quickbird or Ikonos imagery. This bundle contains a 2.5m resolution panchromatic band, three 10m resolution multi-spectral bands, and a 20m-resolution short wave IR band. We request SPOT 5 Level 1A processed imagery. Level 1A imagery has been previously corrected by normalizing CCD response to compensate for radiometric variations due to detector sensitivity.

Once we have acquired a SPOT 5 scene, we begin by geometrically rectifying the panchromatic and multi-spectral bands. We then generate a natural color image using the red, green, and near IR bands in the image. SPOT 5 does not produce a blue band as other sensors do. Using the bands supplied the image appears as a false color image, as shown in Figure 5.

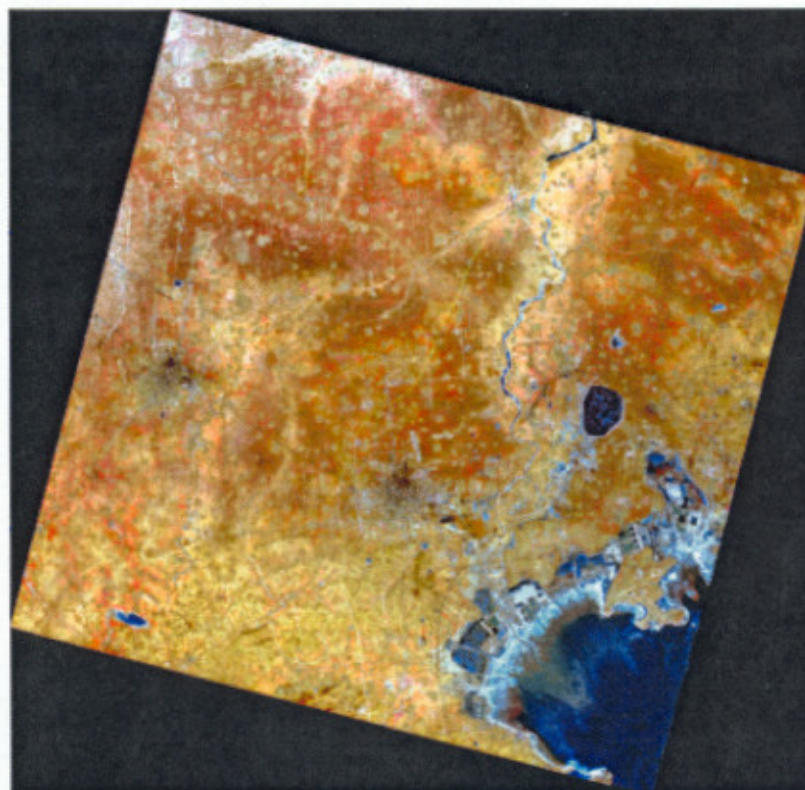


Figure 5: False color view of input SPOT 5 imagery without blue spectral band.

In order to generate a natural color image using this data we must implement a spectral band transformation. This transformation is given below

$$\begin{aligned}R_N &= 0.9(R') + 0.1(\text{NIR}') \\G_N &= 0.7(G') + 0.3(\text{NIR}') \\B_N &= G'\end{aligned}$$

Where: R_N = Natural Color Red Band
 G_N = Natural Color Green Band
 B_N = Natural Color Blue Band

R' = Input SPOT 5 Red Band
 G' = Input SPOT 5 Green Band
 B' = Input SPOT 5 Blue Band

Implementing this transform produces the natural color image shown in the figure below.

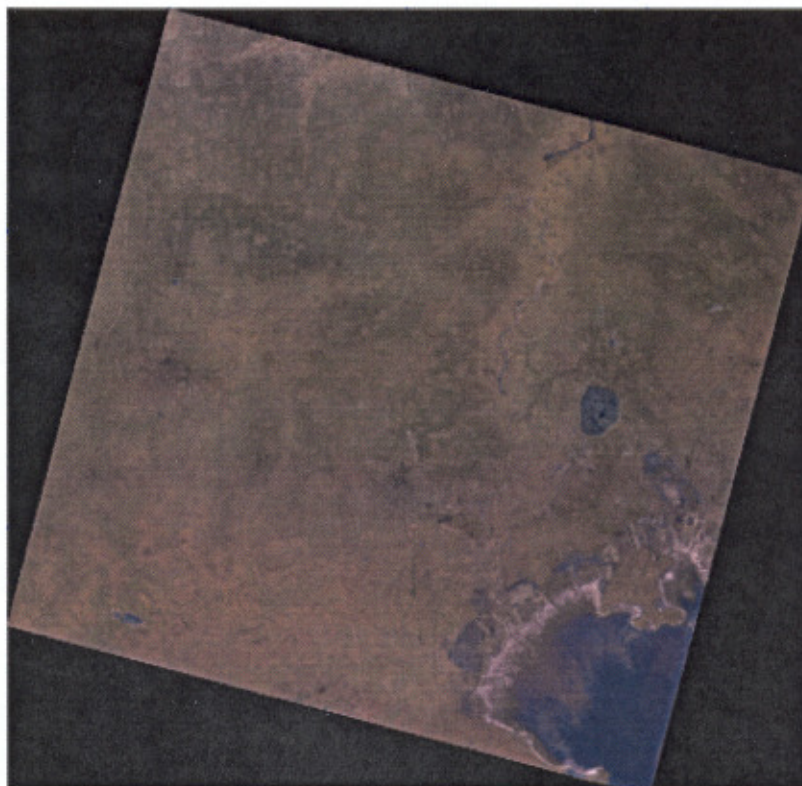


Figure 6: Natural color view of SPOT 5 imagery after transformation.

Once we have rectified the SPOT 5 imagery and have created a natural color image, we are ready to refine the features in the scene. In this case we have already extracted features over this scene using the Landsat 7 ETM+ imagery. These features may now be overlaid onto the rectified SPOT 5 scene. We then examine the features to determine whether they need to be spatially refined. If so, we update the features and save these refined features. Because we can identify smaller features using the higher resolution SPOT 5 imagery, we then augment the feature set based upon this information. As we receive more SPOT 5 imagery, we repeat the process and ensure feature alignment across the image seams. We also ensure tonal balancing between the low resolution Landsat scenes and the high resolution SPOT scenes. Finally, we export the Landsat and SPOT 5 scenes separately, the attributed feature data and the elevation data for further integration into the scene generation process.

5. Integration with Paint the Night (PTN) IR Scene Generation

Paint the Night (PTN) is a real-time infrared imaging sensor simulation allowing the user to view scenes in a 3-D virtual world as if through a real or notional imaging sensor. PTN was developed initially to aid the Army in: sensor

design, prototyping, and analysis; search and target acquisition model development; evaluation of tactics, techniques and procedures; and automatic target recognition training and analysis. Because PTN was designed primarily for the ground or low altitude surveillance tasks critical to the Army mission; PTN represents all terrain objects as discrete geometry and does not utilize overhead imagery directly as textures. Terrain objects include roads, rivers, trees, and buildings. All are represented as 3-D geometry and attributed with material classifications and geo-typical textures.

In order to generate the virtual representation of a geo-specific area, PTN must be provided geographic information about that area in the form of 3-D geometry along with rendering information for that geometry. The format that information is stored in at runtime effects the performance of the simulation. It is therefore necessary to compile and pre-process that data into an efficient runtime database prior to execution. Our terrain build process takes GIS information about a geo-specific area and convert it into the required 3-D formats for Paint the Night, called a PTN terrain database.

Because PTN functions in concert with a SAF (Semi-automated Force), used to coordinate vehicle movements, the terrain representations used by each must be correlated. The SAF requires similar geo-specific information, which it uses to determine movement and intervisibility of the military units involved in its simulated war-fighting exercise. To ensure the necessary correlation between SAF terrain and PTN terrain both representation should be created from the same source data and using the same approximations. Our build process for the terrain takes the same GIS information and creates a SAF terrain database.

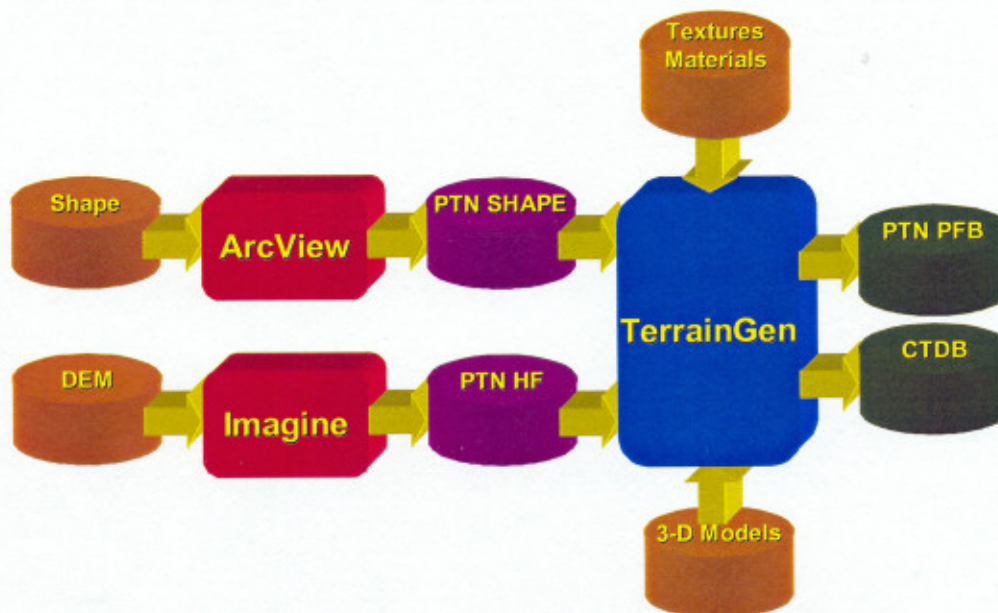


Figure 7: PTN Terrain Build Process.

In this effort, we are taking the MsDB data and converting it to PTN and SAF runtime database. Feature information in the MsDB will be in ESRI Shape format and the elevation information in DEM format. The imagery in the MsDB will only be used as a reference. Our existing tools are functional but are limited in their ease of use and inefficient for manipulating large-scale databases such as the one required for this project. In preparation for the database build Night Vision is upgrading these tools. The dataflow is shown in Figure 7 followed by an explanation of these upgrades.

This process is based on utilizing commercial tools wherever available and a redesigned terrainGen (PTN terrain generation code). A conceptual drawing of the new terrainGen code is depicted in Figure 8. This new design organizes the terrain generation functions into a core process with plugins for input and output. All the necessary geometric manipulations occur in the core process to ensure that the terrain formats remain correlated. We are only planning to support a single input format for elevation and feature data. The feature input format will be Shape to

correspond with the MsDB. Our input elevation data will be in a raw binary format with file format and geographic information stored in a separate XML file in order to achieve maximum flexibility. The terrain builder is required to convert other input data formats to our standards and do additional manipulations or projections using ArcView and/or Imagine. We plan to output only our virtual (pfb) and the one constructive format (ctdb) initially, but if a format changes or another one is added it will be much easier to support it using this architecture. The other major change is the incorporation of a GUI, this will not be simply a cosmetic change, by making the process more intuitive we should be able to reduce the errors in the build process and cut our rebuild time.

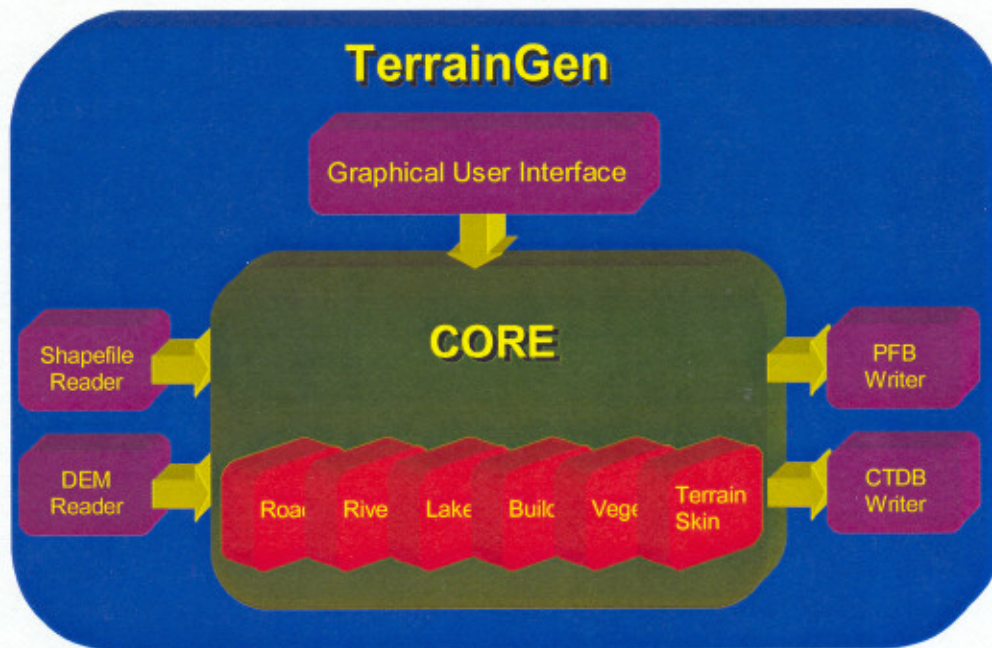


Figure 8: Conceptual Design of the New terrainGen Code.

In addition to generating our PTN databases and SAF database, we are also providing 3-D geometry to Boeing in OpenFlight format for conversion and use in MMRS. The OpenFlight files are created by importing our PTN pfb files into Alias|Wavefront's Maya using an in-house pfb reader plugin and outputting OpenFlight files.

6. Integration with Multi-Mode Radar Simulation (MMRS) Synthetic Aperture Radar (SAR) Generation

The AFRL team made considerable progress integrating the simulators source database (SDB) into the MMRS. The SDB here is defined as the database derived from raw data sources such as high altitude multi-spectral imagery, NIMA data, etc. One of the end objectives of this effort is to define a complementary MMRS / SDB architecture such that the SDB will automatically format, using the MMRS Formatter software, into a MMRS runtime database without any human intervention. This complementary architecture would maximize the fidelity and data content of the simulated radar imagery. The team is mutually working together and making changes in either the SDB or the MMRS / MMRS formatter that makes the most sense that best achieves these goals.

For example, one of the architectural issues addressed was the definition of trees in the SDB. The SDB contained triangles textured with images of trees without additional information. Under these circumstances the MMRS would process the geometry of the vertical plane surfaces, or none if viewed edge on, into an unrealistic radar return. Once this anomaly was identified it became evident that by adding additional information to the tree references such as the type of tree, size, etc. that the MMRS formatter software would automatically replace the polygon with high fidelity radar tree models. The MMRS would then automatically process these models to such effects as seasonal changes; translucency effects resulting from different transmitted frequencies, etc.

Progress was also made by expanding the MMRS formatter to accommodate different, but correct, OpenFlight building model conventions used in the SDB than traditionally formatted by the MMRS.

Other issue currently in work is how best to refine elevation anomalies between ocean and terrain boundaries. Most, if not all, commercial terrain polygon rendering tools result in shorelines with water having terrain elevation polygons. Depending on radar mode, aircraft elevation, look angle, these differences can result in incorrect and misleading radar imagery.

The MMRS was also modified to support new versions of Linux. Unfortunately MMRS runtime libraries compiled under one version of Linux needed to have its Make Files reworked in order to compile under a newer Linux version.

7. Integration with SubrScene Out-The-Window Generation

SubrScene provides a visual interface or scene generator for the OTW database. As the MsDB is designed to fit several needs, modifications to the data received from RTTC and NVL are needed. The visual portion of the database is focused on fast moving aircraft above 10,000 ft., while databases for PTN and MMRS are being optimized for IR and radar. Thus, the database for OTW is being optimized while still maintaining feature origins. The SubrScene visual software supports several database pager formats. These include a fast-page featureless database format unique to SubrScene, the TerraPage format, and a generic Large Area Tile Page pager. Output in each of these pager formats will be generated for both testing and platform optimizations.

Integration and development of the MsDB for SubrScene is being done in three distinct passes. The first pass involves testing the visual data generated from RTTC. OTW imagery and elevation data will be converted to the SubrScenePage (SSP) format. This database will not include any features or culture. Since this process is relatively simple, it will only take a few hours to produce a usable database. As with all databases, your product is only as good as the data you begin with.

The second pass is designed to take the PTN database product and apply visual textures and materials to rapidly produce a usable version of the MsDB. In this pass the created geometry will be modified using in-house tools to search for and replace select attributes of the database. Alterations in this second pass will be focused on Level of Detail (LOD) and material properties of the data. In addition, textures will be replaced to give the database the look and feel of the visual spectrum. A cliptexture of real imagery will be applied to cover the generic terrain skin. However, since the complexity and resolution of data used by PTN is extremely high, performance for this second cut will likely be an issue. Essentially, the product will be a geometric clone of the PTN database with visual attributes and LOD scaling added to better approximate the visual spectrum. Cutting areal features into the terrain skin will complete the second pass of the database generation process.

The first two passes of this process serve primarily to quickly produce usable databases for the visual system. The third and final pass will generate a product directly from the source data. COTS products such as TerraVista and MultiGen will be used to combine visual imagery, elevation data, and cultural features registered by RTC into a platform-targeted database. The level of fidelity for the COTS generated visual database will be selected based on the target platform and the simulation requirements. Outputs from both products are supported in SubrScene and the process of taking that generated data to run-time is trivial.

8. Current Status and Road Ahead

8.1 PTN

At the time of this writing, the modules for reading the feature and elevation data are complete. The PFB writer is completed. And a limited function terrainGen core exists supporting roads, rivers, and trees. The CTDB writer is still in progress. The graphical user interface is only in the design stage, but an XML based project file and appropriate readers have been developed. The early versions of the software will run on the command line using a hand generated XML project file for user input. Additional integration is still necessary before we have a functioning version. In addition modules for building and lake must still be integrated into the core. We have completed the test build using our existing toolset.

8.3 MMRS

The MMRS is gradually being integrated into the AFRL system. Refinement of SDB issues will continue to emerge as new features are added, unrealistic radar effects identified, and as requirements evolve. The team will address these issues as they are identified and corrections implemented where appropriate. Current issues still open are shoreline elevation anomalies and the further identification of entities that are candidate for replacement with higher fidelity models. Transmission towers is one candidate example.

9. Summary

AFRL/VAC has developed a process for constructing large-area 3-D multispectral terrain databases to support Simulation Based R&D (SBR&D) concept development simulation, research and T&E activities. The Multispectral database (MsDB) development effort was intended to investigate a database development approach built from multispectral/hyperspectral imagery and elevation data that also incorporates material classification data capable of supporting realistic out-the-window visual and multispectral terrain displays and weapons/sensor models. Integrating the MsDB into these legacy models enabled us to develop cockpit representations that immerse the warfighter, scientist, analyst, and testers into a dynamic environment suitable for engineering level test and evaluation of a multitude of systems.

Author Biographies

MR. JIM ZEH holds a 1980 BS in Electrical Engineering from the University of Cincinnati and a 1987 MS in Computer Science from the University of Dayton. He has over 20 years of experience in Modeling and Simulation to support Air Force Research Laboratory 6.2 and 6.3 research and has authored several conference papers and technical reports. Since coming to the Laboratory in 1981, Mr. Zeh has spent the majority of his career involved with advanced cockpit simulations. Since 1983, Mr. Zeh has been assigned a simulation team lead for several advanced simulations projects including: STOL/Maneuver Technology Demonstrator F-15; Integrated Control and Avionics for Air Superiority and the Joint Strike Fighter Virtual Strike Warfare Environment (VSWE). Mr. Zeh is currently the project lead for the Simulation Based Research and Development effort within the Air Force Research Laboratory. This involves coordinating the Simulation Based Research and Development effort throughout the Department of Defense, NASA, Industry, and Academia.

DAN CAUDILL received a BS Degree in Aerospace Engineering from the University of Cincinnati in 1989. Mr. Caudill has worked for the Air Force Research Laboratory's Simulation Assessment Branch (AFRL/VACD) since 1989 and has more than 11 years of technical experience in developing and conducting various flight simulation experiments. Currently, Mr. Caudill is the Lead Simulation Engineer for the JSF Project at AFRL/VACD.

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ROB SUBR received his BS Degree in Computer Engineering from University of Idaho in 1995. He was commissioned into the Air Force in 1995 and worked at the Air Force Research Lab providing simulation support for numerous Air Force programs. As a Veridian engineer, he supplies technical experience in visual simulation for the Joint Strike Fighter Project at AFRL/VACD.

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ERIC LESTER received his BS in Electrical Engineering in 1995 and his MS in Electrical Engineering, specializing in digital image processing and pattern recognition, from the University of Tennessee, Knoxville. Mr. Lester has authored several publications in the area of imagery and LADAR processing. He served as the lead image processing engineer at the NIMA Custom Product Activity in Reston, VA in from 1999 – 2000. Currently Mr. Lester is the Chief Image Processing Engineer at CG2, Inc. in Huntsville, AL. In this capacity he leads a number of geospatial image processing projects and business development efforts in this area.

KARL SPUHL received his MS Degree in Electrical Engineering in 1968 from St. Louis University and his BS Degree from Washington University in St. Louis in 1959. Mr. Spuhl has worked for the Boeing Company for the past 41 years and has been working in Flight Simulation for over 33 years. He has been working with real-time person-in-the-loop air-to-ground radar simulation and database generation for the past 26 years. Mr. Spuhl is an Engineer Scientist supporting the Center for Integrated Defense Simulation at Boeing. He is an Adjunct Professor at Washington University and has been teaching engineering for the past 19 years.